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54 Laser Micro Beam Analysis Device

Laser micro beam analysis device, in which a laser beam (24) is deflected by means of an optical element, for example a mirror (36) with a middle aperture (28). The reflected light is focused on the surface of the sample (14) to be examined by means of a condenser (20) which also features a middle aperture. The impacting laser beam produces secondary particles that reach the particle detector (18) through the two apertures (28, 22) for analysis of the surface. In this way, the maximum value of the secondary distribution can be recorded.

[Diagram]
Probe = Sample – 14 *analyse* = analysis – 18

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Laser Micro Beam Analysis Device

Patent claims

1. Laser micro beam analysis device for analysis of the secondary particles produced with a light beam by means of light beams on the surface of a sample, characterized by

- an optical part (36, 32) for changing the axis of the beam (24), in which the part (36, 32) features an aperture (28, 34),

- a condenser (20) for absorbing the beam (24) from the optical part (36, 32) and for focusing and directing the beam (24) on the surface along the first axis, in which the condenser (20) features an aperture, and by

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- a detector (18), which is arranged along a second axis for absorbing the particles, which run through the aperture (22) of the optical part (36, 32) and the condenser (20), and which is separated from the sample (14) by means of the optical part (36, 32) and condenser (20) for analysis of the particles, whereby the beam runs through the apertures (22, 28, 34) of the optical part (36, 32) and the condenser (20).

2. Device according to claim 1, characterized by the light source being a laser.

3. Device according to claim 1, characterized by the condenser (20) being arranged parallel to the surface of the sample (14), and the aperture (22) of the condenser (20) being arranged in its center.

4. Device according to claim 3, characterized by the first axis running vertically to the surface of the sample (14) and coinciding with the second axis.

5. Device according to claim 3, characterized by the light source being a laser, and the profile of the beam's (24) intensity featuring a notch in its middle zone.

6. Device according to claim 3, characterized by the optical part being a prism (32).

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Laser Micro Beam Analysis Device

The invention concerns a laser micro beam analysis device according to the above concept of claim 1, and in particular concerns an analysis device that works with a laser micro beam.

Figure 1 shows a schematic of a typical analysis device that uses a laser micro beam. In this figure, a laser beam 10 is focused on a narrow zone of a sample 14 using a focusing lens 12. Due to the laser beams, secondary particles 16, such as electrons, ions and neutral particles, are produced. The secondary particles 16 are recorded using an analysis device 18, which ascertains the chemical nature of the sample in different ways. The type of the analysis device of course depends on the kind of secondary beam captured.

With such ordinary laser micro beam analysis devices, it is impossible to arrange the focus lens 12 between the sample 14 and the analysis device 18, since the lens 12 absorbs the secondary particles or would at least have an effect on the secondary particles 16.

As a result of this difficulty in arranging the analysis device 18 between the focus lens 12 and the sample 14, the analysis device is customarily arranged on one side, as depicted in figure 1. For this reason, difficulties arise in the construction of the analysis device 18 regarding its size and assembly, as well as regarding the selection of an optimal focal length of focusing lens 12.

In the case of an ion analysis, a spatial distribution appears for the number of ions produced using the laser beam at a maximum value Y_o for an angle that lies perpendicular to the surface of a sample, and decreases with the distance from this angle, as depicted in figure 2. This means that when Y is the number of ions normally produced in a direction with an angle of 0, Y is expressed by the equation

$$Y = Y_o \cos\theta.$$

Considering the limited sensitivity of the analysis device, an attempt will be made to arrange the analysis device 18 on a line corresponding to the vector Y_o; that is, perpendicular to the surface of the sample. However, with such an arrangement it is impossible to illuminate the sample with a laser beam perpendicular to the sample surface. A non-perpendicular laser beam 10, though, produces an elliptical form of the focused laser beam on the sample surface, so the analysis is made even more difficult.

Therefore, it is the task of the present invention to create a laser micro beam analysis device of the kind initially named that will remedy the disadvantages of the known device so that the extent to which secondary beams are captured is maximized without making the analysis more difficult. In doing so, the impacting laser beam and the captured secondary beams should run coaxially.

This task is solved with the invention described in claim 1.

This means that a laser micro beam analysis device is created that features an optical element, e.g. a mirror with an aperture. The mirror changes the optical angle of the laser light and reflects it in the direction of the sample. The analysis system also includes a condenser lens with an additional aperture. The lens collects the laser light, whose optical axis was changed using the optical element, and radiates a narrow zone of the sample's surface with the focused light. Moreover, the system includes an analysis device for analyzing the secondary particles that were produced by the laser light and pass through the apertures of the lens and mirror.

Design examples of the invention are depicted in the illustration and are described in more detail in the following.
They show:

Figure 1 a structure of an ordinary laser micro beam analysis device;

Figure 2 a diagram for depicting the spatial distribution of secondary production;

Figure 3 the structure of a laser micro beam analysis device according to one of the invention's first design forms;

Figure 4	a front- and side-view of the mirror used in the design form according to figure 2;
Figure 5	a front- and side-view of the condenser lens used in the design form according to figure 2;
Figure 6A and 6B	intensity distribution of the laser light; and
Figure 7	front- and side-view of one of the prisms used in an additional design form

An initial design form of the present invention will be described in the following with reference to figure 3. A condenser lens has a middle aperture 22. The condenser lens 20 absorbs a collimated laser light beam 24 from a laser 26. A reflecting mirror 26 has a middle aperture 28 and is arranged at a 45° angle to the original laser beam 24 and likewise to the surface of the sample 14, so that the laser beam 24 is reflected by 90° and directed perpendicularly in the direction of the surface of the sample 14. The two apertures 22 and 28 are arranged on a common norm to the surface of the sample 14. The condenser lens 20 is arranged between the reflective mirror 28 and sample 14 so that it can collect, or focus, laser light on a small zone of the surface of sample 14. An example of an investigated sample is semiconductor material.

The largest components of particle distribution of the secondary radiant beam produced using a laser light from sample 14 occurs along the norm to the surface of sample 14. This maximum portion of the secondary beam 30 arrives through the middle aperture 22 of the condenser lens 20 and then through the middle aperture 28 of the mirror 26. It finally reaches the analysis device 18, which is arranged on the same running norms through the two apertures 18 and 20. The analysis device can be operated in different ways to determine the composition of the small zone of sample 14 according to the secondary particles captured in the analysis device 18.

Figure 4 shows an example of the reflective mirror 36 with its middle aperture 28. The left side shows an overview, and the right side shows a cross-section. On the left side, figure 5 shows an overview of the condenser lens 20 with its middle aperture 22. On the right side, a corresponding cross-section is depicted.

By providing the two middle apertures 22 and 28 in the condenser lens 20 and in the mirror 36, is possible to arrange the analysis device 18 along the axis of the impacting light perpendicular to the surface of the sample. On this axis, the maximum of secondary particle distribution is available.

The intensity distribution of an ordinary laser light beam is depicted in figure 6A. This distribution corresponds to a Gaussian distribution with a single maximum. It is possible to use such a laser beam with a Gaussian distribution with the device specified by the invention. The reflective mirror 36 and the condenser lens 20, however, have corresponding middle apertures 20 and 22. This means that the maximum portion of the laser light intensity is lost when passing through the apertures and cannot be used, which results in a considerable loss of laser energy.

In order to keep the energy loss to a minimum, it is preferable to use a laser beam that features a spatial distribution with a middle indentation, as depicted in figure 6B. With this type of beam, a portion of the laser beam near the middle aperture 28 of the mirror 36 is lost through opening 20, but this is a smaller portion than that of the Gaussian laser beam.

This means that more light is reflected, and the system's degree of effectiveness is improved.

In the design form described above, the reflective mirror is used as an optical system to alter the direction of the laser beam. The reflective mirror 36 can also be replaced by a prism 32 with a middle opening 34, as depicted in an overview and a side view in figure 7. In addition, the condenser lens 20 does not have to be designed as a single piece lens, as it is depicted here, but can be designed as a combination of different lenses.

Although the design form described above is a laser micro beam analysis device, the present invention can also be used with the same effectiveness in a laser processing device, in which the analysis device is used for determining the vaporized material during laser processing.

As described above, an analysis device for determining secondary particles (or beams) is created with the invention. The analysis device can be arranged in such a way that it absorbs the secondary particles that are illuminated in the same direction that the laser light illuminates the sample. The system uses an optical element with an opening that can alter the optical axis of the laser light beam. The system also includes a condenser lens with an additional opening for focusing the laser light in order to direct it on a small zone of the sample surface.

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Figure 1
State of the art

18 – analysis

14 – sample

Figure 2

Figure 2

Figure 4

Figure 6A
LASER INTENSITY

DISTANCE FROM THE BEAM MIDPOINT

Figure 5

Figure 6B
LASER INTENSITY

DISTANCE FROM THE BEAM MIDPOINT

Figure 7